

WHAT IS CLAIMED IS:

1. A computer-implemented process for segmenting writings written on a whiteboard work surface, comprising the process actions of:

5 capturing images of a whiteboard that includes one or more items projected on the whiteboard and writings written on the whiteboard with a camera; and

separating into two files the one or more items projected on the whiteboard and the writings written on the whiteboard.

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2. The computer-implemented process of Claim 1 further comprising the process action of transmitting the file containing the writings written on the whiteboard to remote participants.

15 3. The computer-implemented process of Claim 1 further comprising the process action of archiving the file containing the writings written on the whiteboard.

20 4. The computer-implemented process of Claim 1 wherein the one or more items projected on the whiteboard comprises an electronic presentation.

5. The computer-implemented process of Claim 1 wherein the one or more items projected on the whiteboard comprises annotations received from remote participants.

6. The computer-implemented process of Claim 1 wherein separating into two files the one or more items projected on the whiteboard and the writings written on the whiteboard comprises the process actions of:

5 determining a relationship between the position of the camera view and the one or more items projected on the whiteboard via geometric calibration;

determining a relationship between the colors of the writings written on the whiteboard and the colors of the writings written on the whiteboard captured in the images via color calibration;

10 estimating a visual echo image that corrects a captured image to match the whiteboard in geometry and color using the results of the geometric calibration and the color calibration;

using visual echo cancellation to isolate writings written on the whiteboard by comparing the ratio of the albedo of the captured image to the albedo of the
15 visual echo image.

7. The computer-implemented process of Claim 6 wherein the visual echo comprises annotations from remote participant and projected content.

20 8. The computer-implemented process of Claim 6 wherein if the ratio of the albedo of the captured image to the albedo of the visual echo is less than 1, then a given pixel[x,y] belongs to the writings if and only if

1-(albedo ratio for the sum of the red, green and blue color channels)/3 is greater than (the sum of the variances of the pixel for the red, green and blue color channels)/(the sum of the visual echoes for the pixel for the red, green and blue color channels).

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9. The computer-implemented process of Claim 8 wherein for a pixel [x,y] that belongs to the writings, for a given color channel, the color in the captured image can be corrected by multiplying its albedo ratio for the given channel by 255.

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10. A computer-implemented process for identifying content written on a whiteboard comprising the process actions of:

obtaining geometric calibration data determining the geometric relationship between a whiteboard and a view of said whiteboard captured by a camera;

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obtaining color calibration data determining the color relationship between the color of writings written on the whiteboard and the color of writings written on a whiteboard in an image captured by said camera;

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capturing an image of said whiteboard having projected content and writings written on the whiteboard;

calculating a visual echo of the captured image by correcting the color and geometry of the captured image using the geometric calibration data and the color calibration data; and

using the ratio of the albedo of the captured image to the albedo of the visual echo to identify writings on the whiteboard.

11. The computer-implemented process of Claim 10 further comprising
5 the process actions of:

segmenting out the identified writings; and
transmitting the segmented writings to a remote site for display.

12. The computer-implemented process of Claim 10 further comprising
10 the process actions of:

segmenting out the identified writings; and
saving the segmented writings for later viewing.

13. The computer-implemented process of Claim 10 wherein obtaining
15 geometric calibration data comprises the process actions of:

projecting a sequence of rectangular patterns onto the whiteboard
and simultaneously capturing the sequence of rectangular patterns in a
sequence of images;

detecting the corners of the rectangular patterns in the sequence of
20 images captured with the camera; and

using the correspondences between the locations of the corners in
the sequence of images and the corners of the rectangular patterns on the

whiteboard to estimate a homography that defines the geometric relationship between the camera view and the whiteboard.

14. The computer-implemented process of Claim 13 wherein detecting
5 the corners comprises the process actions of:

converting the images to grayscale images;
using edge detection to detect edges of the rectangles in the
grayscale images thereby creating an edge map;
using a Hough transform to detect straight lines on the edge map;
10 fitting a quadrangle for each of the rectangles using the detected
straight lines; and
finding the corners of the quadrangle.

15. The computer-implemented process of Claim 10 wherein obtaining
15 the color calibration data comprises the process actions of:

quantizing red, green, blue color space into bins;
for each of the set of quantized colors,
projecting a known color onto the full whiteboard that is
divided into sub-regions;
20 taking n images of said known color projected on the
whiteboard with a camera and storing said n images;
warping each of said n images into whiteboard coordinates
using the homography found by the geometric calibration;

calculating the mean and variance of each color across n frames for each sub-region; and

creating a lookup table of the mean and variance of each sub-region for said known color.

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16. The computer-implemented process of Claim 10 wherein if the ratio of the albedo of the captured image to the albedo of the visual echo is equal to 1, then nothing is written on the whiteboard.

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17. The computer-implemented process of Claim 10 wherein if the ratio of the albedo of the captured image to the albedo of the visual echo is less than 1, then there are writings written on the whiteboard.

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18. The computer-implemented process of Claim 10 wherein if the ratio of the albedo of the captured image to the albedo of the visual echo is less than 1, then a given pixel[x,y] belongs to the writings if and only if

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$$1 - (\text{albedo ratio for the sum of the red, green and blue color channels})/3$$
 is greater than $(\text{the sum of the variances of the pixel for the red, green and blue color channels})/(\text{the sum of the visual echoes for the pixel for the red, green and blue color channels})$.

19. The computer-implemented process of Claim 18 wherein for a pixel [x,y] that belongs to the writings, for a given color channel, the color in the

captured image can be corrected by multiplying its albedo ratio for the given channel by 255.

20. A computer-readable medium having computer executable
5 instructions for providing contents written on a whiteboard to remote meeting participants, said computer executable instructions comprising:

obtaining geometric calibration data determining the geometric relationship between a whiteboard and a view of said whiteboard captured by a camera;

10 obtaining color calibration data determining the color relationship between the color of writings written on the whiteboard and the color of writings written on a whiteboard and the color of the writings written on the whiteboard in an image captured by said camera;

capturing an image of said whiteboard having projected content
15 and writings written on the whiteboard;

calculating a visual echo of the captured image by correcting the color and geometry of the captured image using the geometric calibration data and the color calibration data; and

using the ratio of the albedo of the captured image to the albedo of
20 the visual echo to identify writings on the whiteboard.

21. A system for segmenting a clear image of a whiteboard work surface for remote collaboration comprising:

a camera capturing one or more images of a whiteboard that includes one or more items projected on the whiteboard and writings written on the whiteboard; and

a visual echo cancellation module for separating into two files the one or more items projected on the whiteboard and the writings written on the whiteboard.

22. The system of Claim 21 further comprising:

a remote site with a display for displaying the one or more items projected on the whiteboard and writings written on the whiteboard; and

a network for sending said the one or more items projected on the whiteboard and writings written on the whiteboard to said remote site.

23. The system on Claim 21 wherein the writings written on the whiteboard and the one or more items projected on the whiteboard are sent to the remote site in two separate files.

24. The system of Claim 22 wherein the remote site has the capability to send back annotations to the whiteboard to be displayed with the one or more items projected on the whiteboard.

25. The system of Claim 20 wherein the visual echo cancellation module for separating into two files the one or more items projected on the

whiteboard and the writings written on the whiteboard comprises sub-modules for:

obtaining geometric calibration data determining the geometric relationship between a whiteboard and a view of said whiteboard captured by a camera;

obtaining color calibration data determining the color relationship between the color of writings written on the whiteboard and the color of the writings written on the whiteboard in an image captured by said camera;

capturing an image of said whiteboard having projected content and writings written on the whiteboard;

calculating a visual echo of the captured image by correcting the color and geometry of the captured image using the geometric calibration data and the color calibration data; and

using the ratio of the albedo of the captured image to the albedo of the visual echo to identify writings on the whiteboard.

26. The system of Claim 25 wherein if the ratio of the albedo of the captured image to the albedo of the visual echo is less than 1, then a given pixel[x,y] belongs to the writings if and only if:

$$1 - (\text{albedo ratio for the sum of the red, green and blue color channels})/3 \text{ is greater than } (\text{the sum of the variances of the pixel for the red, green and blue color channels})/(\text{the sum of the visual echoes for the pixel for the red, green and blue color channels}).$$

27. The system of Claim 26 wherein for a pixel [x,y] that belongs to the writings, for a given color channel, the color of the writings in the captured image is corrected by multiplying its albedo ratio for the given channel by 255.

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28. The system of Claim 27 wherein for a pixel [x,y] that belongs to the writings, for a given color channel, the color in the captured image can be corrected by:

choosing four classes of color corresponding to the most commonly
10 used markers used to mark on the whiteboard;

recovering the set of writings;

correcting the color of the writings in the captured image for the red,
green and blue color channels;

converting the color of the writings from red, green and blue color
15 space to hue, saturation and intensity color space to create a new image;

manually defining writings corresponding to the four classes of
color and histogramming these writings by hue, saturation and intensity; and

evaluating the probability the each pixel in the new image belongs
to one of the four classes based on the histogram.

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